

TITLE: AN ASSESSMENT OF THE ACCURACY OF ANALYTICAL MODEL PLANNING IN ORTHOGNATHIC SURGERY

AUTHORS: Dr.M.Baskaran MDS FDSRCS(Eng),Dr.S.Sindhuja Devi,Dr.I.Packiaraj MDS,Dr.K.Retnakumar MDS Dr.Gen Morgan MDS,Dr.Alaguvel Rajan MDS, Dr. Abdul Rahman MDS.

ABSTRACT:

The purpose of this study was to assess our method of analytic model planning in achieving a planned maxillary movement for the correction of a dentofacial deformity. Five patients who underwent maxillary orthognathic surgery, at a minimum, were included in the study group. For each study subject, consistent analytic model planning with splint fabrication was used to establish the desired horizontal repositioning of the maxilla. External reference points and internal reference points were used to establish the vertical dimension. Using preoperative and 5-week postoperative lateral cephalometric radiographs, analysis was designed to assess the difference between the planned and actual movement of the maxilla. The average difference between the planned and actual 5-week postsurgical vertical movement of the maxilla was $\geq 1\text{mm}$ ($P < 0.05$). For horizontal movements of maxilla, the mean difference between the planned and actual obtained movements of maxilla was not statistically significant both cephalometrically and in model surgery ($P > 0.05$).

INTRODUCTION:

Precise surgical repositioning of the maxilla according to patient-specific functional and aesthetic objectives is essential in orthognathic surgery. The most reliable method to transfer the planned maxillary movements at surgery is through the use of a prefabricated splint.⁽¹⁻⁴⁾ The

effectiveness of the prefabricated intermediate splint in turn depends on accurate model planning methods that capture the desired maxillary reorientation (pitch, yaw, roll), and movements (vertical, horizontal), according to surgical objectives. One of the essential parameters from which to judge the effectiveness of model planning is the accuracy of the horizontal (sagittal) repositioning of the maxilla.

Published studies in which an intermediate splint is utilized to achieve the preferred horizontal maxillary repositioning in the operating room, report a wide range of variation between the planned and the actual outcome.^{5–15} Therefore, the reliability of analytic model planning remains in question. The purpose of this study was to assess our method of analytic model planning used in everyday practice to achieve the desired movement of the maxilla.

MATERIALS AND METHODS:

A consecutive series of patients ($n = 5$) who underwent, at a minimum, Le Fort I osteotomy for correction of a dentofacial jaw deformity, were included in the study group. The sample consisted of females ($n = 3$) and males ($n = 2$), with a mean age of 21 years (range 14–35 years). The surgery was carried out by a single surgeon at Rajas Dental College. Perioperative orthodontic treatment was completed to remove dental compensation and to align the arches in all patients. Consistent surgical technique, and inpatient and outpatient management through the initial 5 weeks of convalescence was carried out. All study subjects underwent: (1) preoperative and 5-week postoperative lateral cephalometric radiographs of acceptable quality with a metric reference frame for analysis; (2) consistent presurgical facial analysis by the surgeon, including millimeter decisions concerning planned horizontal and vertical repositioning, and reorientation (pitch, roll, yaw) of the maxilla; (3) consistent analytic model surgery planning with splint

construction(intermediate and final); (4) use of theprefabricated splint to establishthe maxillary positioning after Le FortI osteotomy prior to plate and screw fixation;and (5) use of consistent intraoperativelandmarks to confirm vertical orientation (medial canthus to maxillarycentral incisor).

Determination of the preferred surgical repositioning of the jaws was based on a combination of direct visual examination, analysis of the lateral cephalometric radiograph, and analysis of the profile facialphotograph taken during a presurgical office visit. The extent of preferred maxillary horizontal movement in millimeters was ultimately assessed by the surgeon with the patient in the natural head position (NHP) during the direct visual examination.

METHODS OF ANALYTIC MODEL PLANNING:

Our routine analytic model planning requires: face-bow registration of the maxillary plane in relationship to the NHP (Earpiece type Face bow HANAU™ 008824-000; Whip Mix Products, Louisville, KY, USA), a chin point guidance technique to capture the occlusion in centric relation(CR)¹⁶⁻¹⁸ and alginate impressions of the maxillary and mandibular dentition. In thelaboratory, the maxillary cast is mounted with the two face-bow arms parallel to the upper arm of the semi-adjustable articulator(010889-000 HANAU WIDE-VUE ARCON Articulator was used; Whip Mix Products, Louisville, KY, USA the #8500 Articulator was used;Whip Mix Products, Louisville, KY,USA) to establish the maxillary plane in relationship to the NHP. The mandibularcast is then mounted to the maxillary cast using the CR inter-occlusal registration obtained in the office setting. The vertical height of the articulator pin is established and then maintained during the model planning.

Four consistent reference points are marked on each maxillary cast. These reference points are used for baseline measurements on the Erickson model platform. The reference points used are the mesial buccal cusp of each maxillary first molar and the midpoint of each maxillary central incisor edge. The prescription for maxillary movements determined by the surgeon is then added to these baseline measurements. The maxillary model is released from the articulator and repositioned according to the new measurements. The desired surgical repositioning of the maxilla is confirmed using the Erickson model platform. The splint is then fabricated using the static mandibular position on the articulator as a platform.

At operation, the planned vertical facial changes are confirmed using external reference landmarks (e.g., medial canthus to mid-maxillary central incisor distance in mm on each side) and internal reference marks (bur holes on either side of the osteotomy cut).

METHODS USED TO MEASURE RESULTS:

For each study patient, a presurgical standard cephalometric radiograph was obtained for later analysis. At 5 weeks after surgery, a similar standard cephalometric radiograph was also taken. This was timed to coincide with removal of the surgical splint.

For each study patient, the maxillary cast was mounted on the articulator with respect to the NHP. The horizontal axis of the NHP has been shown to closely approximate the radiologic landmark of Frankfurt horizontal (FH). Therefore, for the purposes of this study, a cephalometric analysis using a reference plane parallel to FH was designed to measure the linear change achieved at the maxillary incisal edge.

Four landmark points (sella, nasion, porion, and orbitale) that were unchanged from the orthognathic surgery were used in the analysis. Therefore these points could be used to create a consistent reference line from which a linear measurement (e.g., change in horizontal position of the maxillary incisors) could be made prior to and after surgery. A perpendicular reference line (perpendicular to FH) passing through sella, called the sella perpendicular, was then dropped. From sella perpendicular, a direct linear measurement was made parallel to FH and extending to the maxillary incisal edge (U1). To assess accuracy of the horizontal repositioning of the maxillary incisors at operation, the distance in mm (sella perpendicular to U1) was measured on both the preoperation and 5-week postoperation lateral cephalogram. The measurements were then adjusted using a metric reference frame to correct for magnification. Any difference in length of these two data points will correspond to variation in the preoperative and postoperative (at 5 weeks after surgery) horizontal position of the maxillary central incisors. Comparison between the planned and actually obtained horizontal position of the maxillary incisors at 5 weeks was made using the paired t-test. Statistical significance was set at $P < 0.05$. Associations between the planned and postsurgical results were investigated with Pearson's correlation. Using the paired t-test, method errors of cephalometric measurements taken from the radiographs were defined by repeating the measurements for all 20 patients in a random order.

In addition, Post-operatively face bow transfer done and maxillary and mandibular models were articulated in Hanau articulator. The position of maxillary incisor both in vertical and horizontal dimension is measured in Erickson model platform.

Results

The data collected for all study patients are presented in Table 1. The patient example (patient 1 in Table 1) from whom cephalometric radiographs are used to demonstrate the study methods of measurement (Fig. 1) is shown in Fig. 2. In all cases, the surgically achieved and maintained (at 5-week post-operation) horizontal movement measured at the maxillary incisors both cephalometrically and in model surgery were within 1.0 mm of that planned. For vertical movements of maxilla, the mean difference between the planned and actual obtained movements of maxilla was not statistically significant cephalometrically ($P > 0.05$). But the model surgery measurements showed statistically high significant difference between the planned and actual obtained movements of maxilla ($P < 0.05$).

In one case where Lefort I osteotomy alone was performed, there was no difference between the planned and actual obtained vertical movements of maxilla cephalometrically. But there was a 2.5mm forward movement of maxilla which was not planned. In pre and post-op model surgery assessment, there was a 0.26mm difference between the planned and actual obtained vertical movement of maxilla and a 1.6mm forward movement of maxilla.

In the three cases, where Lefort I osteotomy was associated with anterior maxillary osteotomy, there was a difference of ≥ 1 mm between the planned and actual obtained vertical movement of maxilla cephalometrically. In pre and post-op model surgery assessment also, there was a difference of ≥ 1 mm between the planned and actual obtained vertical movement of maxilla. In case of horizontal movement, except in one case, the difference

between the planned and actual obtained movement of maxilla was $\leq 1\text{mm}$ both cephalometrically and in model surgery.

In one case where Lefort I osteotomy was associated with BSSO, the difference between the planned and actual obtained vertical movement of maxilla was less than 0.5mm cephalometrically and in model surgery. Also the Model surgery measurements pre and post-operatively showed no difference between the planned and actual obtained horizontal movements of maxilla.

DISCUSSION:

The accuracy of Orthognathic surgery depends on two main steps: paper surgery to model surgery and model surgery to real surgery. In our study, a splint is fabricated to position the maxilla in the three spatial planes. The vertical dimension is obtained using the ERP.

Many studies have evaluated the ability of surgeons to accurately reposition the maxilla during surgery using different techniques. The methodology in our study was based on manual tracings. Although digital or manual tracing was possible, in both methods the cephalometric points are located manually, and so human errors in landmark location remain, and digitization of the image actually increases the risk of errors. Powers et al concluded, from comparing manual and digital tracings, that software errors may result in clinically significant miscalculations ⁽²³⁾.

Establishment of the planned vertical height of the maxilla requires additional reference points in the operating room. We use the external reference points of the medial canthus to the mid central incisor on each side. This assists in establishing the planned vertical repositioning of the maxilla. The use of other external reference landmarks has been described (e.g., K-wire in glabella region).²⁶⁻²⁹ The technique described in our study used both IRP and ERP.

A.M.O'Malley⁽¹⁸⁾ tried to investigate possible differences in anteroposterior steepness between three semi-adjustable articulators, whether differences in skeletal pattern have any influence on the steepness of the occlusal plane, and finally whether these differences affect the surgical planning for maxillary or mandibular osteotomies. All three articulators namely, DenarMkII, Dentatus Type ARL, WhipmixQuickmount 8800 positioned the occlusal plane less steeply (5° , 6.5° , 2° respectively) to the Frankfort plane than that measured on the cephalogram. For Hanau articulator, it flattened the occlusal plane by 5° . For every 1° that the occlusal plane is flattened on the articulator compared with reality, the upper incisors look 1° more retroclined on the articulator. So whatever articulators clinicians use, the steepness of the occlusal plane of the mounted models has to be evaluated. In our study, to confirm the accuracy of the mounted maxillary cast, the mounted Frankfort(MF) and the Frankfort horizontal(FH) are drawn on a lateral cephalometric radiograph and it should be within 7° .

Review of the literature⁽⁴¹⁾ by Olga-ElpisKolokitha revealed that, besides factors directly related to the prediction method and its use, there exist a considerable number of factors which would affect significantly the accuracy of soft tissue response. These could be biological ones such as relapse, center of mandibular rotation and individual variation in response to treatment and others such as gender, race, pre-operative soft tissue thickness and data bases for mean ratios of soft to hard tissue movement changes.

Both manual and computerized cephalometric prediction methods are two-dimensional and cannot describe accurately three-dimensional phenomena.

SUMMARY AND CONCLUSION:

To summarize, the results of our study show a difference of $\geq 1\text{mm}$ between the planned and actual obtained vertical movement of maxilla. In case of horizontal movements of maxilla, there was no significant difference between the planned and actual obtained movements of maxilla.

The results show that the internal reference points and external reference points used in our study method was unable to place the maxilla as planned in the vertical dimension.

In case of horizontal movements of maxilla, our method of face bow transfer and model surgery using Erickson model platform for splint fabrication was accurate in placing the maxilla as planned horizontally.

It appears that our positioning of is, in comparison, is within the range of most of the studies using extra oral points. It might be that the endeavor invested in the measuring procedure, be it intraoral or extra oral is more important than the method as such.

The environment and the number of surgeons involved in the surgery also significantly influence the precision of Orthognathic surgery.

To improve the surgical accuracy, we must strive to reduce the range of random variation by careful and rigorous treatment planning and model surgery, by exactly performed surgery according to the treatment plan, and by including double-checks of all intraoperative measurements.

To conclude, we found that on the whole the repeatability was satisfactory. On a practical level, a 1mm variance is unlikely to be detected by the patient nor it is relevant clinically. Also the most important question in assessing surgical results has to do with each patient's level of satisfaction with the end result (i.e. esthetics and function). All our patients expressed satisfaction

with their esthetic and functional outcome after Orthognathic surgery. But, since Orthognathic surgery is elective, it is imperative that the surgeon strive to provide the patient with the most accurate surgical repositioning possible.

REFERENCES:

1. H.Lockwood;A Planning technique for segmental osteotomies. Br J Oral Maxillofac Surg.1974; 12:102-105.
2. M.Anwar,M.Harris;Model surgery for Orthognathic surgery. Br J Oral Maxillofac Surg.1990; 28:393-397.
3. W.D.Polido,E.Ellis III,D.P.Sam:An assessment of the predictability of maxillary repositioning. .Int.J.Oral maxillofac.Surg.1991;20:349-352.
4. A.M.McCance,J.P.Moss,D.R.James:Lefort I Maxillary osteotomy:is it possible to accurately produce planned pre-operative movements? Br J Oral Maxillofac Surg.1992; 30:369-376.
5. D.C.BryanN.P.Hunt.Surgical accuracy in Orthognathic surgery. Br J Oral Maxillofac Surg.1993; 31:342-350.
6. S.Hillerup,J.Bjorn-Jorgensen,O.Donatsky,P.U.Jacobsen:Precision of Orthognathic surgery.A Computerized cephalometric analysis of 27 patients. Int.J.Oral maxillofac.Surg.1994;23:255-261.
7. D.C.Bryan;An investigation in to the accuracy and validity of three points used in the assessment of autorotation in Orthognathic surgery. Br J Oral Maxillofac Surg.1994; 32:363-372.
8. Anders Lundstrom,Fredrik Lundstrom,drOdont:The Frankfort horizontal as a basis for cephalometric analysis: Am J OrthodDentofacial Orthop.1995; 107:537-40.

9. Biljana Trpkova, Paul Major, Narasimha Prasad, Brian Nebbe, M Dent: Cephalometric landmarks identification and reproducibility: A meta-analysis. *Am J Orthod Dentofacial Orthop.* 1997; 112:165-70.
10. Ole Donatsky, Dr Odont, Jens Bjorn-Jorgensen, Michael Holmqvist-Larsen, and Sorenhillerup: Computerized cephalometric evaluation of Orthognathic surgical precision and stability in relation to maxillary superior repositioning combined with mandibular advancement or setback. *J Oral Maxillofac Surg.* 1997; 55: 1071-79.
11. . Edward Ellis III: Bimaxillary surgery using an intermediate splint to position the maxilla. *J Oral Maxillofac Surg.* 1999; 57: 53-56.
12. Thomas H. Lapp: Bimaxillary surgery without the use of an intermediate splint to position the maxilla. *J Oral Maxillofac Surg.* 1999; 57: 57-60.
13. Jing Hu, Dazhang Wang, Songjiao Luo, Yangxichen: Differences in soft tissue profile changes following mandibular setback in Chinese men and women. *J Oral Maxillofac Surg.* 1999; 57: 1182-1186.
14. Edward Ellis III. Bimaxillary surgery using an intermediate splint to position the maxilla. *J Oral Maxillofac Surg.* 1999; 57: 53-56.
15. Curtis M. Becker: Mandibular centricity: centric relation. *J Prosthet Dent.* 2000; 83: 158-60.
16. DH Hartzell, AJ Maskeroni, FC Certosimo: Techniques in recording centric relation. *Operative dentistry* 2000; 25: 234-236.
17. Paul stella: The predictability of inferior medial canthus as a stable external vertical reference point in maxillary repositioning surgery. *Int J Adult Orthod orthognath Surg* 2000; 15: 305-308.

18. A.M.O'Malley,A.Milosevic:comparison of three face bow/semi-adjustable articulator systems for planning Orthognathic surgery. . Br J Oral Maxillofac Surg.2000; 38:185-190.
19. KarimA.Mobarak,Olaf Krogstad,LisenEspeland,TorsteinLyberg: Factors influencing the predictability of soft tissue profile changes following mandibular setback surgery.Angle Orthod 2001;71:216-227.
20. . Jaime Gateno,Kim K.Forrest,Brian Camp:A comparison of 3 methods of face-bow transfer recording:Implications for Orthognathic surgery. J Oral Maxillofac Surg.2001; 59: 635-640.
21. T.K.Ong,R.J.Banks,A.J.Hildreth:Surgical accuracy in Lefort I Maxillary Osteotomies. Br J Oral Maxillofac Surg.2001; 39:96-102.
22. S.Loh,J.K.Heng,P.Ward-Booth,L.Winchester,F.McDonald:A radiographic analysis of computer prediction in conjunction with Orthognathic surgery. Int.J.Oral maxillofac.Surg.2001;30:259-263.
23. Ron Jacobson,David M.Sarver:The predictability of maxillary repositioning in Lefort I Orthognathic Surgery. Am J OrthodDentofacial Orthop.2002; 122: 142-54.
24. Tae-Geon Kwon,Yoshihide Mori,katsuhirominamiand Sang-han Lee: Reproducibility of maxillary positioning in Lefort I osteotomy:A 3-dimensional evaluation. J Oral Maxillofac Surg.2002; 60: 287-293.
25. GilancarioRenzi,Andrea Carboni,Maurizio Perugini:Intraoperative measurement of maxillary repositioning in a series of 30 patients with maxillomandibular vertical asymmetries.Int J Adult OrthodorthognathSurg 2002;17:111-115

26. Banu Cakirer, David Dean, Juan Martin palomo, Mark Guenther Hans: Orthognathic surgery outcome analysis: 3-dimensional landmark geometric morphometrics. *Int J Adult Orthod orthognath Surg* 2002; 17: 116-132.
27. Virgilio f. ferrario, Chiarella Sforza, Graziano Serrao, Johannes H. Schmitz. Three-dimensional assessment of the reliability of a postural face-bow transfer. *J Prosthet Dent*. 2002; 87: 210-5
28. L' Tanya J. Bailey, Lucia H. S. Cevidanes, William R. Proffitt. Stability and predictability of Orthognathic surgery. *Advances in Orthodontics & dentofacial surgery. Am J Orthod Dentofacial Orthop*. 2004; 126: 273-7.
29. Steven Semaan; Mithran S. Goonewardene; Accuracy of a Lefort I Maxillary osteotomy. *Angle Orthod* 2005; 75: 964-973.
30. . G. Power, J. Breckon, M. Sherriff, F. Mc Donald: Dolphin Imaging software: An analysis of the accuracy of cephalometric digitization and Orthognathic prediction. *J Oral Maxillofac Surg*. 2005; 34: 619-626.
31. M. Modig, L. Andersson, I. Wardh. Patients perception of improvement after Orthognathic surgery; Pilot study. *Br J Oral Maxillofac Surg*. 2006; 44: 24-27.
32. J. N. Gil, J. D. P. Claus R. Mantro, S. M. Lima Jr: Predictability of maxillary repositioning during bimaxillary surgery: accuracy of a new technique. *Int. J. Oral maxillofac. Surg*. 2007; 36: 296-300.

33. James L.Ackerman,William R.Proffitt,DavidM.Sarver,Marc B.Ackerman,Martin R.Kean:
Pitch,roll,and yaw:Describing the spatial orientation of dentofacial traits.Am J
OrthodDentofacial Orthop.2007; 131:305-10.
34. Jeffrey c.posnick,John Wallace.Complex Orthognathic surgery:Assessment of patient
satisfaction.J Oral Maxillofac Surg.2008; 66: 934-942.
35. Fraser Walker,Ashraf F.Ayoub,KhursheedF.Moos, Joseph Barbenel:Face bow and
articulator for planning Orthognathic surgery:1facebow.Br J Oral Maxillofac Surg.2008;
46:567-572.
36. W.B.Kretschmer,W.Zoder,G.Bacut,Mihaelabacuit,k.Wangerin;Accuracy of maxillary
positioning in bimaxillary surgery. Br J Oral Maxillofac Surg.2009; 47:446-449.
37. Kyu-Gin Song,Seung-HakBaek,Seoul.Comparison of the accuracy of the three-
dimensional virtual method and the conventional manual method for model surgery and
intermediate wafer fabrication.Oral Surg Oral Med Oral pathol Oral RadiolEndod
2009;107:13-21
38. Jose Nazareno Gil,Felipe Eduardo baitres Campos,Jonathas Daniel Paggiclaus,luiz
Fernando Gil,Charles marin,segio Fernando Torres de Freitas. Medial canthal region as an
external reference point in Orthognathic surgery. J Oral Maxillofac Surg.2011; 69:352-
355.
39. Daniel Perez,Edward Ellis III;Sequencing Bimaxillary surgery:Mandible first. J Oral
Maxillofac Surg.2011; 69: 2217-2224.
40. Timothy Turvey:Sequencing of two-jaw surgery:The case for operating on the maxilla
first. . J Oral Maxillofac Surg.2011; 69:2225.

41. . Olga-ElpisKolokitha,EvangeliaChatzistavrou:Factors influencing the accuracy of cephalometric prediction of soft tissue profile changes following Orthognathic surgery.J Maxillofac.Oral Surg.(Jan-Mar 2012)11(1);82-90.
42. N.Park,J.C.Posnick:Accuracy of analytic model planning in bimaxillary surgery.Int.J.Oral maxillofac.Surg.2013;42:807-813.
43. Alfred Chee-ching Tsang,Alfred Siu Hong Lee,Wai Keung Li:Orthognathic model surgery with LEGO Key-spacer.J Oral Maxillofac Surg.2013; 71: 2154.e1-2154.e9.
44. T.G.Kwon,J.W.Choi,H.M.Kyung,H.S.Park:Accuracy of maxillary repositioning in two-jaw surgery with conventional articulator model surgery versus virtual model surgery. Int.J.Oral maxillofac.Surg.2014;43:732-738.
45. Wolford LM,Hilliard FW,Dugan DJ(1985) Surgical treatment objective.A systematic approach to the predictive tracing.Mosby Year Book.St Louis,pp 54-74
46. ProffitWR(1991) Treatment Planning:the search for wisdom.In:Proffit WR,White Rp(eds) Surgical orthodontic treatment.Mosby year Book,St Louis,pp 142-191.



